JOURNAL OF ANIMAL SCIENCE
The Premier Journal and Leading Source of New Knowledge and Perspective in Animal Science

Growth of Holstein dairy heifers in the United States

A. J. Heinrichs and W. C. Losinger

J Anim Sci 1998. 76:1254-1260.

Growth of Holstein Dairy Heifers in the United States

A. J. Heinrichs* and W. C. Losinger†

*Department of Dairy and Animal Science, The Pennsylvania State University, University Park 16802 and †Centers for Epidemiology and Animal Health, National Animal Health Monitoring System, USDA Animal and Plant Health Inspection Service, Veterinary Service, Fort Collins, CO 80521

ABSTRACT: Data were collected on the heart girth (n = 8,565; a measure of body weight) and height at withers (n = 8,568) of Holstein dairy heifers from 659 dairy farms as part of the National Dairy Heifer Evaluation Project during 1991 and 1992. Means and standard deviations for weight and height were determined for ages .5 to 23.5 mo. Third-order polynomial regression equations were derived to study the relationship of weight and height to age. Stepwise mixed-model regression, using REML estimation, was used to identify factors associated with Holstein heifer growth and to build a multivariate model describing Holstein heifer growth across the United States. Holstein heifers on the sample of dairy farms in this study were heavier and taller at the withers than standards published 30 to 50 yr ago. Increased rolling herd average milk production was associated with a greater rate of growth in Holstein heifers. Holstein heifers in the West and Midwest were larger at a given age than those in the Northeast and Southeast.

Key Words: Dairy Cows, Growth, Height, Weight

 J. Anim. Sci. 1998. 76:1254–1260

Introduction

Early studies of heifer growth (Ragsdale, 1934; Matthews and Fohrman, 1954; Davis and Hathaway, 1956; Heinrichs and Hargrove, 1987) were restricted in size or scope to one or a limited number of farms, thereby limiting the application of the results. The earliest growth standards were based on experiment station herds (Ragsdale, 1934; Matthews and Fohrman, 1954; Davis and Hathaway, 1956). Heinrichs and Hargrove (1987) developed the first growth standards from a population-based sample, but they limited the data to Pennsylvania. The present study was the first national U.S. study to address dairy heifer growth. When the early growth standards (Ragsdale, 1934; Davis and Hathaway, 1956) are compared with the ones from the 1950s and ones from the 1980s (Matthews and Fohrman, 1954; Heinrichs and Hargrove, 1987), height and weight have increased in the later data sets from 5 to 15% at a given age for these heifers.

A limitation of many of the previous studies was that operations were not selected to permit estimates and inferences related to larger populations (King, 1990; Moore et al., 1991). The principle objective of this research was to develop a current appraisal of the growth of Holstein heifers in a sample of U.S. dairy farms. A further objective of this study was to develop a model to evaluate management factors collected from this study that may be related to dairy heifer growth.

Materials and Methods

The National Dairy Heifer Evaluation Project (**NDHEP**), conducted by the USDA, Animal Plant and Health Inspection Service Veterinary Service, was designed to measure baseline management and health of U.S. dairy replacement heifers (Heinrichs et al., 1994). The National Agricultural Statistical Services (**NASS**) producer list, from which a probability sample design was used to select participants for the National Dairy Heifer Evaluation Project (NDHEP), included nearly all agricultural producers in the United States (Heinrichs et al., 1994). Participation in the NDHEP was limited to operations with ≥ 30 dairy cows in 28 states representing 78% of the U.S. dairy cow population (Heinrichs et al., 1994). To adjust for incompleteness of the NASS producer list, all operations that had ≥ 30 dairy cows and that were within certain randomly selected land areas in the United States were contacted for the NDHEP. The sample selection method used created the greatest

Received April 21, 1997.
Accepted December 21, 1997.

likelihood that virtually every dairy herd in the U.S. had a known probability of being selected (Heinrichs et al., 1994). On each participating farm, federal or state animal health officials collected body measurements from ≤ 10 heifers in three age groups: weaning to 4 mo, 4 mo to breeding age, and breeding age to calving. Measurements were made once per heifer and included heart girth as an estimate of weight (Davis et al., 1961), height at withers, and date of birth. Heart girth was converted to body weight using a calibration equation (Heinrichs et al., 1992). Milk production and other herd management data were also collected (Heinrichs et al., 1994). Officials were trained on the proper procedures to use in measuring height at withers and weight of heifers as part of a national workshop for the overall National Dairy Heifer Evaluation Project.

A total of 8,565 usable BW measurements and 8,568 wither height measurements were collected from 659 Holstein farms. Of the measurements not included in the analysis, 387 were from heifers greater than 732 d of age or from heifers with BW or height greater than 4 SD from the mean for a given month. Age was determined to the nearest half-month from birth date and date of measurement by alternately cumulating 30- and 31-d intervals. Mean, standard deviation, and median for BW and wither height of heifers in the final data set were determined once per heifer for a variety of ages from .5 to 23.5 mo. Third-order regression equations for mean BW and wither height as a function of age in months were fitted to these data to describe the population further, as was done previously (Heinrichs and Hargrove, 1987).

To examine growth by herd production level, herds were sorted by low (< 7,258 kg), medium (7,258 to 9,072 kg), and high production (> 9,072). This type of comparison has previously been shown to be a method to differentiate herd management types (Heinrichs and Hargrove, 1987). Third-order regression equations of median BW and wither height as a function of age in months were determined.

In regional analyses of the data, regions used were West (California, Oregon, Washington, Idaho, and Colorado), Midwest (Minnesota, Nebraska, Iowa, Wisconsin, Illinois, Indiana, Ohio, and Michigan), Northeast (Pennsylvania, New York, Vermont, Maine, Massachusetts, Connecticut, and Rhode Island), and Southeast (Maryland, Virginia, North Carolina, Tennessee, Georgia, Alabama, and Florida).

To identify management factors associated with Holstein dairy heifer growth, the SAS Mixed procedure (SAS, 1985) was used to apply REML estimation (Searle et al., 1992) to the following model:

$$\text{LWEIGHT} = \text{LAGE} + \text{REGION} + (\text{LAGE} \times \text{REGION}),$$

where LWEIGHT represents the natural logarithm of the weight of the Holstein heifer; LAGE represents the natural logarithm of the age of the heifer; and REGION is a categorical variable representing one of four regions: West, Midwest, Northeast, and Southeast. The LAGE × REGION term represents the interaction between LAGE and REGION. The dairy operation identifier (FARMID), nested within REGION, was specified as a random effect (Swartz, 1978).

As a variable screening mechanism, each of the management variables considered for inclusion in the model (Appendix 1) was added separately to the model, and a separate MIXED procedure was run for each new model. The model statement appeared thus:

$$\text{LWEIGHT} = \text{LAGE} + \text{REGION} + (\text{LAGE} \times \text{REGION}) + \text{VAR1} + (\text{LAGE} \times \text{VAR1}),$$

where VAR1 represents the management variable under consideration. All management variables were categorical. The term FARMID nested within each combination of REGION and VAR1 was specified as a random effect.

Schwarz's Bayesian criterion (**SBC**) was used to analyze each management variable (Swanson, 1967). If the value for SBC for the model with the management variable added was greater than the value for SBC for the reduced model, which had REGION alone, then the management variable was deemed to have passed the initial screening. To avert multicollinearity in the model, the SAS CORR procedure was used to compute Spearman rank correlation coefficients at the dairy operation level for the screened variables (Swanson, 1967; Hogg and Craig, 1978).

The model with the screened variable that resulted in the highest value for SBC was considered the new reduced model, and the other screened variables were added individually to this model. The model building process continued in a stepwise fashion until the addition of any new variable or removal of any accepted variable resulted in a decrease in the value of SBC.

The MIXED procedure was used to generate parameter estimates for the final model and to achieve comparisons in expected Holstein weights between different factor values at specific ages (SAS, 1985).

Results and Discussion

General herd characteristics from this study related to the U.S. dairy herds have been summarized (Heinrichs et al., 1994). The data had 42.6% of heifers from farms with < 100 cows, 27.3% with 100 to 200 cows, and 30.2% with > 200 cows. The weights and heights at the withers for the entire data set are presented in Table 1. The number of heifers evaluated at a given age is similar to or greater than that in previous data sets (Davis and Hathaway 1956; Miller and McGilliard, 1959; Heinrichs and Hargrove, 1987).

Table 1. Mean body weights and heights of heifers by age in all herds

Age, mo	No. of heifers	Weight, kg		Height, cm	
		$\overline{X}$	SD	$\overline{X}$	SD
.5	27	53.1	8.7	79.4	3.3
1.5	267	77.2	18.7	84.2	5.4
2.5	996	96.1	18.1	88.0	5.0
3.5	1,202	118.5	20.8	92.0	5.2
4.5	897	141.3	25.6	96.4	5.9
5.5	653	168.1	31.8	100.8	6.1
6.5	523	191.0	33.4	104.3	6.8
7.5	420	214.9	39.4	107.6	6.4
8.5	380	243.2	48.5	110.2	6.1
9.5	293	265.5	47.6	113.6	6.1
10.5	242	286.6	48.3	115.4	5.9
11.5	203	308.6	48.4	118.3	6.0
12.5	240	332.5	65.4	120.1	6.3
13.5	237	358.9	69.0	123.1	7.6
14.5	238	380.7	63.6	123.8	6.9
15.5	200	409.3	61.4	126.0	5.8
16.5	199	427.3	66.3	127.2	6.2
17.5	214	443.7	63.5	128.9	5.4
18.5	195	458.2	65.1	129.4	5.1
19.5	189	477.7	77.4	129.7	6.3
20.5	205	493.6	82.0	131.6	6.1
21.5	176	516.2	80.2	133.0	6.4
22.5	182	523.4	84.5	133.4	6.7
23.5	187	528.9	99.4	134.6	7.0

However, the number of farms represented in the sample population is greater in the present data set.

The mean for each month of age was fitted to a third-order regression equation on age for weight and height (Table 2). To describe the population further, separate third-order regressions for BW and height were fitted to the mean + and – 1 SD. Holstein heifers in this study are similar in BW and height to Holstein heifers from a statewide population survey conducted in Pennsylvania during 1985 (Heinrichs and Hargrove, 1987), as presented in Table 3. The current study, however, used a more modern conversion factor to estimate live BW from heart girth measurements (Heinrichs et al., 1992). Heifers in the national data set are slightly smaller in body weight at ≤ 5 mo of age and slightly heavier at ≥ 16 mo, although the current data are well within 1 SD of the previously reported data (Heinrichs and Hargrove, 1987). Height at withers of the heifers in the current data set are all within 1 to 2 cm of values derived in a previous study (Heinrichs and Hargrove, 1987). Thus, the size of dairy heifers does not seem to have increased during this time period. Data summarized by Hoffman (1997) show recommended body size variables for heifers raised under ideal management conditions; and they are similar to values obtained from the mean + 1 SD from Table 2.

Table 4 presents the third-order regression equations for BW and wither height as functions of age by herd milk production category. As in previous studies (Heinrichs and Hargrove, 1987), herds that had greater mean milk production had heifers with greater

Table 2. Regression parameter estimates for weight and height for all herds

Dependent variable	Intercept	Regression coefficients: Linear	Quadratic	Cubic	R^2
Weight					
Mean	44.239**	19.789**	.561**	–.022**	.99
Mean +1 SD	48.306**	26.566**	.254**	–.014**	.99
Mean –1 SD	40.172**	13.011**	.868**	–.030**	.99
Height					
Mean	76.270**	5.262**	–.162**	.002**	.99
Mean +1 SD	79.755**	6.050**	–.228**	.003**	.99
Mean –1 SD	72.785**	4.475**	–.097**	.0002**	.99

$^{**}P < .01$.

Table 3. Comparison of weight and height values with previous data sets

Age, mo	Ragsdale, 1934	Davis and Hathaway, 1956	Matthews and Fohrman, 1954	Heinrichs and Hargrove, 1987	NAHMS study[a]
			Weight, kg		
1	50.8	—	54.8	60.4	64.6
3	87.6	97.6	98.1	102.1	108.1
6	161.2	181.1	181.5	167.2	178.4
9	231.1	257.9	258.9	233.5	251.7
12	286.9	319.6	319.4	299.1	324.3
15	338.7	—	367.2	362.1	392.7
18	383.6	419.5	413.0	420.6	453.4
21	432.2	—	465.3	472.6	502.6
24	485.3	521.6	506.1	516.2	537.0
			Height, cm		
1	77.7	—	—	80.4	81.4
3	87.1	89.2	—	89.5	90.6
6	100.8	103.4	—	101.0	102.4
9	110.5	113.1	—	110.3	111.8
12	116.8	119.5	—	117.6	119.2
15	121.7	—	—	123.2	124.9
18	125.2	128.3	—	127.4	129.1
21	128.5	—	—	130.5	132.3
24	131.3	133.3	—	132.7	134.6

[a]NAHMS = National Animal Health Monitoring Service.

BW and wither height at a given age. Part of the difference in heifer growth by milk production level could be attributed to differences in management styles related to herd size.

Table 1 and previous studies of heifer growth revealed a certain degree of heteroscedasticity (Neter and Wasserman, 1974). This means that, as dairy heifers mature, the standard deviation or variability in their body weights increases. In regression analysis, the principal deleterious consequence of heteroscedasticity is that estimates of variance are biased, thus invalidating tests of significance. Therefore, logarithmic transformations were used in analysis of growth to reduce heteroscedasticity and to linearize the regression function.

This study had an unbalanced, hierarchical design (Swartz, 1978). Varying numbers (from 1 to 29) of Holstein heifers were measured per dairy operation, and all calves measured on a dairy operation were assumed to have been managed the same way. The REML estimation, as performed with the SAS MIXED procedure, provided a means to account for these assumptions in the model-building process (SAS, 1985). The variables considered for possible inclusion in the model are listed in Appendix 1.

Spearman rank correlation coefficients for the six dairy operation-level variables that passed the initial

Table 4. Regression estimates for median body weight and height for all Holstein herds by milk production level in the National Dairy Heifer Evaluation Project

Dependent variable	Intercept	Regression coefficients: Linear	Quadratic	Cubic	R^2
Median BW					
Milk Production, kg					
< 7,258	42.895**	13.870**	.986**	–.0353**	>.99
7,258–9,072	32.101**	20.250**	.433**	–.0164**	>.99
> 9,072	14.937	28.039**	–.096	–.0041**	>.99
Median height					
Milk Production, kg					
< 7,258	74.350**	4.747**	–.115*	.0006	>.99
7,258–9,072	72.572**	5.794**	–.197**	.0027**	>.99
> 9,072	71.999**	6.126**	–.217	.0030**	>.99

*P < .05 that the coefficient = 0.
**P < .01 that the coefficient = 0.

Table 5. Spearman rank correlation coefficients for the screened variables[a]

Variable[b]	RHAMP	NURSED	COLOST	STGRAIN	COCCIDIO	IONOPH
RHAMP	1	−.1591 (.0001)	−.0119 (.7640)	.0654 (.0976)	.2270 (.0001)	.2606 (.0001)
NURSED	−.1591 (.0001)	1	−.0906 (.0216)	−.0350 (.3750)	−.0555 (.1595)	−.0723 (.0669)
COLOST	−.0119 (.7640)	−.0906 (.0216)	1	.0357 (.3668)	−.0023 (.9546)	−.0062 (.8759)
STGRAIN	.0654 (.0976)	−.0350 (.3750)	.0357 (.3668)	1	.0267 (.4987)	.0671 (.0890)
COCCIDIO	.2270 (.0001)	−.0555 (.1595)	−.0023 (.9546)	.0267 (.4987)	1	.3315 (.0001)
IONOPH	.2606 (.0001)	−.0723 (.0669)	−.0062 (.8759)	.0671 (.0890)	.3315 (.0001)	1

[a]Figures in parentheses represent $P > |\text{Rho}|$ under H_0: Rho = 0.
[b]RHAMP: rolling herd average milk production. NURSED: calves get first colostrum from nursing. COLOST: Fresh or soured colostrum is fed to calves from 24 h of age to weaning. STGRAIN: Starter grain is fed to calves from 24 h of age to weaning. COCCIDIO: Heifers routinely get coccidiostats in feed from birth to first calving. IONOPH: Heifers routinely get ionophores in feed from birth to first calving.

screening phase for the multivariate model selection process appear in Table 5. Eliminating dairy operations that lacked information for any of the screened variables left 8,363 dairy heifers from 643 dairy operations. Region was forced into the model because of the study design and because heifer growth was expected to vary among regions (Heinrichs et al., 1994). Among the screened variables, rolling herd average milk production was positively correlated with routinely giving coccidiostat and ionophores in feed to heifers from birth to calving, and negatively correlated with the practice of allowing newborn calves to receive their first colostrum from nursing (Table 5). These three management practices are all generally associated with better-managed, higher-producing herds.

Table 6. Parameter estimates for the final model

Parameter	Estimate	SE	T	$P > \|T\|$
Intercept	1.0266	.0465	22.05	.0000
LAGE	.8037	.0087	92.61	.0000
REGION				
West	.0987	.0470	2.10	.0358
Midwest	−.0340	.0413	−.82	.4114
Northeast	−.1486	.0418	−3.55	.0004
Southeast	0	—	—	—
LAGE × REGION				
West	−.0080	.0087	−.93	.3549
Midwest	.0213	.0077	2.75	.0060
Northeast	.3212	.0079	4.12	.0000
Southeast	0	—	—	—
RHAMP				
< 7,258 kg	.2942	.0452	6.51	.0000
7,258 to 9,072 kg	.1652	.0362	4.57	.0000
> 9,072 kg	0	–	—	—
LAGE × RHAMP				
< 7,258 kg	−.0776	.0084	−9.20	.0000
7,258 to 9,072 kg	−.3983	.0067	−5.95	.0000
> 9,072 kg	0	—	—	—
COLOST				
Not fed	−.0960	.0323	−2.97	.0030
Fed	0	—	—	—
LAGE × COLOST				
Not fed	.0136	.0060	2.27	.0231
Fed	0	—	—	—

Table 7. Expected weight (kg) at specific ages for variables in the model

Item	Days of age				
	90	180	208	365	545
Region					
West	106[a]	180[b]	201[b]	309[b]	420[b]
Midwest	106[a]	184[a]	206[a]	322[a]	442[a]
Northeast	99[b]	173[c]	194[c]	306[b]	422[b]
Southeast	100[b]	170[c]	190[d]	294[c]	400[c]
Rolling herd average milk production, kg					
< 7,258	100[b]	167[c]	185[c]	282[c]	380[c]
7,258 to 9,072	104[a]	178[b]	199[b]	310[b]	424[b]
> 9,072	105[a]	186[a]	209[a]	332[a]	462[a]
Fresh or soured colostrum is fed to calves from 24 h to weaning					
Not fed	101[b]	175[b]	195[b]	305[b]	419[b]
Fed	105[a]	179[a]	200[a]	310[a]	423[a]

[a,b,c]Different superscripts within columns indicate different results ($P < .05$).

The parameter estimates for REGION for the final model (Table 6) and the expected weights at specific ages by region (Table 7) show that, for this type of model, looking at either the intercepts or slopes alone does not always yield the correct conclusion. Among the four regions, the West had the highest intercept and the Northeast had the greatest slope. But, taken together, the model showed that Holstein heifer calves in the Midwest had the greatest weight at a given age, particularly from 180 days and beyond. Heifer calves in the West and the Northeast were generally in the middle, and those in the Southeast showed the poorest growth.

The higher intercept in the West may be indicative of greater rates of gain early in life (Table 6). Because preweaned calves were not generally measured, the higher intercept does not necessarily imply a greater birth weight. From 6 mo to 2 yr of age, the model indicates that calves in the Midwest have a greater rate of weight gain than calves in the rest of the country, all other model variables being equal.

The model showed a strong association between heifer growth and rolling herd average milk production (Table 7). Dairy operations that had higher production levels demonstrated greater growth of dairy calves. This may be explained as the result of a combination of higher-quality forage and improved overall nutrition and management with positive impacts on lactation and heifer growth (Moore et al., 1991).

The other variable in the model was the feeding of fresh or soured colostrum to heifers from 24 h of age to weaning. Holding the other variables constant, this practice was associated with approximately a 5-kg increase in weight throughout most of the 2-yr range. Previous studies have indicated improved health and greater weight gain among calves fed colostrum beyond the 1st d of life (Simensen, 1983; Guitau et al. 1994).

Implications

Heifer growth as estimated by the National Dairy Heifer Evaluation Project is different from that presented in studies published 20 yr ago but similar to data presented 8 yr ago in a Pennsylvania-wide study. Increased rolling herd average milk production was associated with greater growth among Holstein dairy heifers. The practice of feeding fresh or soured colostrum to heifers from 24 h of age to weaning was also related to greater growth. Regionally, the Midwest had the greatest body weight for Holstein dairy heifers, and the Southeast the least. This first-ever national assessment of heifer weight and height at withers should be useful for determining population trends of Holstein cattle and to define standards of heifer growth. Differences in feeding strategies in various regions of the United States could explain the different growth rates that were found.

Literature Cited

Davis, H. P., and I. L. Hathaway. 1956. Comparative measurements of Holstein, Ayrshire, Guernsey, and Jersey females from birth to seven years. Nebraska Agric. Exp. Stn. Res. Bull. 179. Univ. of Nebraska, Lincoln.

Davis, H. P., W. W. Swett, and W. R. Harvey. 1961. Relation of heart girth to weight in Holsteins and Jerseys. Nebraska Agric. Exp. Stn. Res. Bull. 194. Univ. of Nebraska, Lincoln.

Guitau, G. K., J. J. McDermott, J. E. Adams, K. D. Lissemore, and D. Waltner-Towes. 1994. Factors influencing calf growth and daily weight gain on smallholder dairy farms in Kiambu district, Kenya. Prev. Vet. Med. 21:179–185.

Heinrichs, A. J., and G. L. Hargrove. 1987. Standards of weight and height for Holstein heifers. J. Dairy Sci. 70:653–660.

Heinrichs, A. J., G. W. Rogers, and J. B. Cooper. 1992. Predicting body weight and wither height in Holstein heifers using body measurements. J. Dairy Sci. 75:3576–3581.

Heinrichs, A. J., S. J. Wells, H. S. Hurd, G. W. Hill, and D. A. Dargatz. 1994. The National Dairy Heifer Evaluation Project: A profile of heifer management practices in the United States. J. Dairy Sci. 77:1548–1555.

Hoffman, P. C. 1997. Optimum body size of Holstein replacement heifers. J. Anim. Sci. 75:836–845.

Hogg, R. V., and A. T. Craig. 1978. Introduction to Mathematical Statistics, Fourth Edition. Macmillan Publishing Company, New York.

King, L. J. 1990. The National Animal Health Monitoring System: Fulfilling a commitment. Prev. Vet. Med. 8:89–94.

Matthews, C. A., and M. H. Fohrman. 1954. Beltsville growth standards for Holstein cattle. U. S. Dept. of Agric. Technol. Bull. 1099. USDA, Beltsville, MD.

Miller, R. H., and L. D. McGilliard. 1959. Relations between weight at first calving and milk production during the first lactation. J. Dairy Sci. 42:1932–1939.

Moore, R. K., B. W. Kennedy, L. R. Schaffer, and J. E. Moxley. 1991. Relationships between age and body weight at calving and production in first lactation in Ayrshires and Holsteins. J. Dairy Sci. 74:269–273.

Neter, J., and W. Wasserman. 1974. Applied Linear Statistical Models. Richard D. Irwin, Homewood, IL.

Ragsdale, A. C. 1934. Growth standards for dairy cattle. Univ. Missouri College of Agric. Exp. Stn. Publ. No. 336.

SAS. 1985. SAS User's Guide: Statistics (5th Ed.). SAS Inst. Inc., Cary, NC.

Searle, S. R., G. Casella, and C. E. McCulloch. 1992. Variance Components. John Wiley & Sons, New York.

Simensen, E. 1983. An epidemiologic study of calf health and performance in Norwegian dairy herds. Factors affecting morbidity and performance. Acta Agric. Scand. 33:65–74.

Swanson, E. W. 1967. Optimum growth patterns for dairy cattle. J. Dairy Sci. 50:244–252.

Swartz, G. 1978. Estimating the dimension of a model. Ann. Stat. 6: 461–464.

Appendix 1: Factors Considered in the Holstein Heifer Growth Model

Region
- West (California, Colorado, Idaho, Oregon, and Washington)
- Midwest (Illinois, Indiana, Iowa, Michigan, Minnesota, Nebraska, Ohio, and Wisconsin)
- Northeast (Connecticut, Maine, Massachusetts, New Hampshire, New York, Pennsylvania, Rhode Island, and Vermont)
- Southeast (Alabama, Florida, Georgia, Maryland, North Carolina, Tennessee, and Virginia)

Herd size (number of preweaned dairy heifers on the operation)
- 0 to 5
- 6 to 15
- 16 or more

Rolling herd average milk production
- Less than 7,258 kg/cow
- 7,258 to 9,072/kg cow
- More than 9,072 kg/cow

The remaining factors were dichotomous (yes/no) variables:

Calves get first colostrum from nursing.

Calves are hand-fed less than 3.79 L of colostrum during first 24 h of life.

Calves are offered grain or other concentrated feeds within first 6 d of life.

Calves are offered hay or other roughages within first 20 d of life.

Calves are offered free choice of water within first 20 d of life.

Average weaning age is ≤ 6 wk.

Average weaning age is ≥ 9.5 wk.

Some heifers are housed in a barn during the winter months.

Some heifers are housed in a group pen during the winter or summer.

Operator or spouse has main responsibility for care of preweaned heifers.

Sex of person who cares for preweaned dairy heifers is male.

Operation visited by a private veterinary practitioner during prior 3 mo.

Average at least 1 h/wk caring for each preweaned heifer.

Whole milk is fed to calves from 24 h of age to weaning.

Fresh or soured colostrum is fed to calves from 24 h of age to weaning.

Medicated milk replacer is fed to calves from 24 h of age to weaning.

Non-medicated milk replacer is fed to calves from 24 h of age to weaning.

Mastitic milk is fed to calves from 24 h of age to weaning.

Antibiotic-containing milk is fed to calves from 24 h of age to weaning.

Starter grain is fed to calves from 24 h to weaning.

Hay is fed to calves from 24 h to weaning.

Haylage is fed to calves from 24 h to weaning.

Silage is fed to calves from 24 h to weaning.

Dairy heifers are knowingly fed animal proteins from birth to first calving.

The herd is closed; no new beef or dairy cattle were accepted in previous 12 mo.

Some calves are born in an individual area in a building.

Heifers routinely get selenium/vitamin E injections from birth to first calving.

Heifers routinely get coccidiostats in feed from birth to first calving.

Heifers are routinely fed or injected with vitamins A-D-E from birth to first calving.

Heifers routinely are fed or injected with selenium from birth to first calving.

Heifers routinely get ionophores in feed from birth to first calving.